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Abstract

Alley farming is an improved fallow technology developed at the International Institute of Tropical Agriculture (IITA) as a sustainable alternative to slash-and-burn systems practiced by farmers in sub-Saharan Africa. Constraints to the use of the technology have been examined, but studies are limited which quantitatively assess determinants of farmers' adoption, and the financial profitability of alley farming under alternative policies. The objectives of this paper are to (i) determine the levels of adoption of alley farming among farmers in Benin, Cameroon, and Nigeria, (ii) examine the socioeconomic, village level, and technology-related factors determining the adoption of alley farming by farmers, and (iii) analyze the effects of policy shifts on the financial competitiveness and social profitability of alley farming and other agroforestry technologies. Survey results reveal that despite earlier skepticism about the adoption potential of alley farming, the actual rates of adoption are encouraging for this complex technology. The analysis conducted with Logit models shows that farmers' socioeconomic characteristics, village characteristics, and farmers' perception of technology attributes were all important in explaining farmers' adoption behavior. The results of the policy analysis matrix (PAM) model show that maize production under agroforestry-based systems is socially profitable and financially competitive when compared to maize production relying only on chemical fertilizer, especially after recent policy shifts. The paper concludes with strategies for targeting alley farming to achieve increased adoption and impact.

Key words: Adoption, alley farming, policy analysis matrix (PAM), profitability, West and Central Africa

Introduction

Traditional agricultural systems in sub-Saharan Africa are characterized by slash-and-burn agriculture (or shifting cultivation) wherein farmers use bush fallows to restore soil fertility. In this system, short cropping periods alternate with long fallow periods. But rapid population growth and land-use pressure have led to a drastic reduction of fallow durations to below the minimum threshold required for the system's sustainability (FAO 1985; Conway 1997), and in some areas, fallow periods have simply disappeared, without the provision of alternative management technologies. This has resulted in increasing degradation of farm land, increasing infestation by weeds, and declining food crop yields, among other negative consequences.

Since the 1970s, the International Institute of Tropical Agriculture (IITA) has researched various options for sustaining crop production. Investigations initially involved the introduction and evaluation of the potential of integrating woody species with food crops as a land-use system for managing fragile lands. The encouraging results of these trials led to the development of alley farming in the early 1980s as one agroforestry system with great promise for the sustainability of small-scale farming systems (Kang et al. 1990, 1991).

Alley farming is an agroforestry system that involves the continuous cultivation of food crops between hedgerows of multipurpose trees on the same land. Woody legumes provide nitrogen-rich mulch and green manure to maintain soil fertility and enhance crop production, and protein-rich fodder for livestock. They help to fix nitrogen, enhance nutrient cycling because of their deep roots, and provide biomass for use as mulch and fodder for livestock. Results of on-station and on-farm trials have shown consistently that alley farming is efficient in reducing soil erosion, improving soil organic matter and nutrient status, and sustaining crop yields under continuous cropping (Atta-Krah and Francis 1987; Kang et al. 1990, 1995). Economic analyses of alley farming have also shown that the system is financially profitable (Ngambeki 1985; Ehui et al. 1990). Several publications have become available covering research results from different parts of the tropics. Recently, Kang et al. (1998) compiled an annotated bibliography of published papers and reports related to alley farming covering various aspects of the technology.

Efforts to promote alley farming research and development in tropical Africa were initiated through the Alley Farming Network for Tropical Africa (AFNETA), a collaborative project of three international agricultural research centers (IARCs), namely IITA, the then International Livestock Centre for Africa (ILCA) now International Livestock Research Institute (ILRI), and the International Centre for Research in Agroforestry (ICRAF), with a number of national agricultural research systems (NARS) in about 20 different countries in all the major agroecological zones in Africa. In Cameroon, extension activities on alley farming and other agroforestry technologies were conducted by research and development agencies such as the World Bank-funded National Agricultural Extension and Training Programme (NAETP), Peace Corps Volunteers (PCVs), and the Center for the Environment and Rural Transformation (CERUT) (Adesina et al. 1997a). In the Republic of Benin, participatory experimentation in agroforestry technologies was initiated in Mono province within the framework of the RAMR project (Recherche Appliquée en Milieu Réel) of the Institut National des Recherches Agricoles au Bénin (INRAB) with the technical support of IITA and the Royal Tropical Institute in Amsterdam. National governmental development agencies (CARDER) and several nongovernmental organizations were also involved in on-farm research and extension activities (Versteeg et al. 1998).

However, realization of the potential benefits of alley farming depends on the diffusion of the system and its adoption by the majority of potential users. The lower than expected speed and level of adoption by farmers led several studies to assess constraints to the "adoptability" of the technology. Constraints identified include nonconducive property rights, especially rights over land and trees; high labor requirements; long periods between the establishment of hedgerows and the accrual of benefits; above- and belowground competition between trees and crops for light, water, and nutrients; and nonadaptability of some of the leguminous trees and shrubs (Atta-Krah and Francis 1987; Carter 1995; Whittome et al. 1995; Dvorak 1996; Sanchez and Hailu 1996).

However, very few studies have examined the adoption of the technology. No study has empirically examined the factors determining adoption or rejection of alley farming technology. Ex post adoption studies are needed to determine the level of adoption of the technology. It is equally important to document the rejection of the technology and the lessons to be learned for technology adaptation. It has been suggested that socioeconomic studies of alternatives to the slash-and-burn agricultural system should put increased emphasis on understanding factors which influence actual adoption decisions of farmers (Sanchez and Hailu 1996; ASB 1997).

Furthermore, although several studies have examined the technical feasibility and productivity of these agroforestry technologies in West and Central Africa, economic studies have not addressed the issue of social costs and returns, and the financial profitability of agroforestry technologies under different policies. No study has examined the role of policies in the uptake of agroforestry technologies. It is well known that the adoption levels of new agricultural technologies can be improved with appropriate policies and institutional support measures that increase farmers' incentives. Policies are important because they shape the prices of inputs and outputs, and influence the relative profitability and competitiveness of technologies. Such studies are needed to guide research and development activities for replacing slash-and-burn agriculture in sub-Saharan Africa.

The objective of this paper was to examine the levels of adoption of alley cropping technologies, and to determine the socioeconomic, institutional, and other farm-level factors that influence the adoption of alley farming and its variants by farmers in Benin, Cameroon, and Nigeria. The paper also analyzes the impacts of policy shifts on the financial competitiveness of maize under various agroforestry technologies, and the social profitability of agroforestry-based technologies for maize production in Cameroon.

Methodology

The material presented in this paper uses primary data from surveys of farmers, 820 in Cameroon, 223 in Nigeria, and 288 in Benin, conducted from June to December 1996 (Adesina et al. 1997a, b). In Nigeria, the survey covered 11 villages in the rainforest, forest-savanna, and savanna agroecological zones. In each zone, villages were first characterized based on several factors, including the presence or absence of agroforestry extension activities, distance to markets, accessibility, and population density. Villages were then stratified, based on whether they had had any extension activities on agroforestry technologies. To ensure representativeness, villages with and without extension activities were selected for data collection. A random sample of 223 farmers was surveyed (142 in southwest Nigeria and 81 farmers in the southeast).

In Cameroon, the survey was a collaborative study involving scientists at IITA, the Institut de la recherche agricole pour le développement (IRAD), and ICRAF, all based in Yaoundé, Cameroon. Three major provinces of the country were covered: Center, Southwest, and Northwest. As in Nigeria, villages were first characterized based on several factors: presence or otherwise of agroforestry extension activities, distance to markets, accessibility, and population density. The total number of farmers in the survey was 820, distributed as follows in the three provinces: 341 (Northwest), 256 (Southwest), and 223 (Center). The same methodology was applied to 288 farmers in the Mono province in southern Benin in collaboration with the Université Nationale du Bénin (UNB).

Two different methods were used to collect data in the villages. Focused group discussions were used to find out the history of land use and deforestation in the villages, fallow management practices and other methods of soil fertility maintenance, land tenurial arrangements, history of the involvement of the villages in on-farm or demonstration trials on agroforestry technologies, importance of livestock, resource scarcities, i.e., scarcity of fuelwood and fodder, and extent of soil erosion. A pretested structured questionnaire was used to collect data on:

- village characteristics: village land pressure, fallow length, fodder supply situation, availability of fuelwood, importance of livestock, and degree of erosion
- farmer characteristics: age, contact with extension, family size, and residence status in the village
- property rights: including modes of land ownership, land rights, and rights on the trees.

Logit models were estimated using LIMDEP 6.0 (Green 1992) by a maximum likelihood method to model farmers' adoption decisions. The dependent variable is ALYF, which indexes if the farmer has adopted alley farming. The variable takes the value of 1 if the farmer currently uses alley farming, and 0 otherwise.

The analysis of financial competitiveness of maize production under alternative technologies was conducted under three time periods using the policy analysis matrix (PAM) (Monke and Pearson 1989; Nelson and Panggabean 1991): (1) the period before fertilizer subsidies were removed, (2) the period after fertilizer subsidies were removed, and (3) the period after the devaluation of the local currency FCFA. The social profitability for these systems at the economic prices was also computed (Adesina and Coulibaly 1998). The agroforestry technologies that were considered in the analysis were tested on-farm by IRAD in the Northern province of Cameroon. Most of the trials were farmer managed. Twenty-one maize production technologies were analyzed, with alternative combinations of local or improved maize grown with fertilizer alone (at three levels: 50 kg nitrogen/ha, 100 kg nitrogen/ha, and 250 kg nitrogen/ha) and/or improved fallow herbaceous legumes such as *Mucuna* and *Tephrosia*. In addition, the study considered alternative cropping with leguminous shrub species such as *Calliandra* and *Sesbania*. Crop budgets were developed for each of these technologies. Costs considered included seed for maize and leguminous species, labor costs for seedling establishment, transplanting, pruning, incorporation of biomass, and amortized costs for small equipment. Nursery costs are relevant only for *Calliandra*.

Results and discussion

Adoption status and current use of alley cropping

Adesina et al. (1997b) examined the status of alley farming in the survey villages following farmers' exposure to information on the technology. Table 1 shows the adoption patterns of alley farming technology in different areas of Nigeria, Cameroon, and Benin.

Table 1. Adoption status and rates of adoption of alley farming technology in Nigeria, Cameroon, and Benin (%)

	Nigeria			Cameroon				Benin
	Total (n = 223)	Southeast (n = 81)	Southwest (n = 142)	Total (n = 820)	Northwest (n = 341)	Southwest (n = 256)	Center (n = 223)	Mono (n = 288)
Heard about	(n = 223)	(n = 81)	(n = 142)	(n = 820)	(n = 341)	(n = 256)	(n = 223)	(n = 288)
Yes	93	88	96	82	84	82	80	78
No	7	12	4	18	16	18	20	22
Use status	(n = 208)	(n = 71)	(n = 137)	(n = 672)	(n = 285)	(n = 211)	(n = 176)	(n = 225)
Adopted	64	59	67	24	27	31	11	32
Experimented	2	1	3	14	15	10	18	–
Not established	33	39	30	61	56	59	72	68
Retention	(n = 139)	(n = 43)	(n = 96)	(n = 256)	(n = 120)	(n = 86)	(n = 50)	(n = 72)
Yes	53	58	51	93	96	94	84	93
No	47	42	49	7	4	6	16	07

Source: Adesina et al. (1997b)

In Benin, of the 288 farmers surveyed, 225 (78%) had heard about the technology. Of the latter, only 72 farmers (32%) had either experimented with it or initially adopted it. The current level of use among this group is encouraging, as 93% continue to use the technology. In Nigeria, of the 223 farmers surveyed, 208 (93%) had heard about the technology, and 66% of them had either initially experimented with it or adopted the technology. Some of the initial adopters had abandoned it, but 53% of these farmers continue to use it. In Cameroon, of the 820 farmers surveyed, 672 (82%) had heard about the technology, and 256 (31%) had either initially experimented with the technology or adopted it. Of this group, 238 farmers (93%) continue to use it. However, wide disparities exist across the country.

In Cameroon, the Northwest province has the highest level of adoption following initial exposure to the technology. Of the 285 farmers who were exposed to the technology, 120 (42%) have established alley farms. Of the 120 farmers, 115 (96%) continue to have functional alley farms. In the Southwest province, of the 211 farmers who heard of the technology 41% have adopted the technology and continue to use it. The Center province has the lowest level of adoption. Of the 176 farmers, only 11% adopted the technology, 18% experimented with it, while 72% never established an alley farm. However, of the farmers who initially established alley farms, 84% have continued to have functional alley farms, while 16% have abandoned the technology. The high level of farmers still having functional alley farms in this area may reflect the more recent introduction of the technology in this province.

In Nigeria, of the 142 farmers surveyed in the southwest, 137 (96%) had heard about the alley farming technology. Among these farmers with exposure to information on the technology, 92 farmers (67%) adopted the technology while 41 (30%) did not adopt it. Among the 92 initial adopters, 49 farmers (51%) have continued to use the technology, while 47 (49%) abandoned it. In southeast Nigeria, 71 farmers (88%) reported that they had heard about the technology. Of this number, 42 (59%) had adopted the technology, while 28 (39%) had not adopted the technology. About 58% of the initial adopters have continued to use the technology, while 42% had abandoned it.

Survey results show that despite earlier skepticism about the adoption potential of alley farming technology (Dvorak 1996), alley farming technology is being adopted by farmers. While these figures are not to be taken as "impacts" of the technology, they nonetheless show that farmers are showing an interest in it.

Reasons for adoption and farmers' adaptation of alley farming technology

In Nigeria, important reasons for farmers' adoption of the technology were mainly soil fertility improvement (82%), production of staking materials and poles (66%), fuelwood (51%), reduction of fallow length (45%), feed for animals (26%), and erosion control (20%). These reasons were variable according to region. For example, the production of fuelwood was important for only 37% in the southwest compared to 80% in the southeast, and the provision of fodder for livestock was important for only 2% in the southwest and yet for 72% in the southeast. In Cameroon, the major reasons for adopting alley farming were improvement in soil fertility (97%), fuelwood production (32%), erosion control (20%), production of staking materials (19%), and reduction in the fallow length (15%).

The study found that farmers are making several modifications to alley farming technology to fit their managerial skills and production systems. What is observed on farmers' fields in some cases does not reflect what was originally recommended by researchers. In several cases, researchers would have considered that the technology had been "abandoned", when in fact farmers are making modifications to the original technology. These modifications include changes in cropping intensity, height of cutback on the hedgerow trees, spacing between the hedgerows, and spacing within the rows.

In Nigeria, 83% of farmers have made modifications to the technology. The most important modification was the introduction of the fallow phase in the alley farming technology resulting in various degrees of cropping intensities on their alley plots. The conventional alley farming technology as recommended by researchers promotes continuous cropping (100% cropping intensities). Survey results show that the mean number of years of continuous cropping on alley plots ranged from 1.76 in the southeast to 3.81 in the southwest. The mean number of years of fallow ranged from 2.28 in southwest villages to 3.72 in southeast villages. Computed mean cropping intensities ranged from 44% in the southeast to 51% in the southwest.

While the study also found that 95% of farmers did not change the conventional approach of tree planting in rows, several other changes were made in the alley farming technology. These include the height at which the hedgerow trees are cut back. Researchers recommended close to knee height above the ground. The study found that 43% of farmers had made modifications to this, and among this group, 83% now cut higher than the recommended level, and 13% below it. Only a few farmers have made modifications in the spacing between the alleys: of these, 80% have expanded the space between the alleys and 20% have narrowed the space.

As in Nigeria, farmers in Cameroon have also made several modifications to alley farming technology. Survey results show that 53% of the 408 alley farmers had made changes in the cropping regimes in alley fields. The highest level of adaptation was found in the Northwest province where 63% changed their cropping regimes. However, only 11% have made changes in the pattern of planting in rows, and 13% have made changes in terms of spacing within the hedgerows.

Similarly, in Benin, farmers have also introduced a fallow phase in the technology. The majority of farmers introduced modifications in pruning frequency and time. While it was recommended that the trees be pruned three times, many farmers often delayed pruning. No farmer pruned more than twice. It was found that 26% of farmers were pruning only once, while the second pruning by the rest of the participants was on average very late (at 7 weeks after planting instead of 2). Farmers made modifications on the “researcher recommended” pruning regime, and modified the spacing within the hedgerows to reduce crop-tree competition (Versteeg et al. 1998). These findings have serious implications on the adoption and future development of alley farming which needs to be more attuned to actual farmer needs.

Constraints to adoption of alley farming technology

Across all villages surveyed in Nigeria, the major reasons for abandoning alley farming after initial adoption are mainly technical and management related. These include too many volunteer seeds which lead to the development of hard-to-clear bush (45% of farmers), high labor demand (40%), nonadaptability of trees (37%), and lack of knowledge of alley farming management (34%). In Cameroon, reasons for the abandonment of the alley farming technology were similar to those in Nigeria. These include lack of information about the technology (45%) and unavailability of seedlings of the hedgerow species (37%). Only 6% indicated limited short-term benefits on soil fertility. In Benin, the major constraints included damage from goats, bush fire, poor soil, and a harmful way of cutting.

Land and tree tenure security were found not to be major constraints to the adoption of alley farming. Results from Cameroon and Nigeria show that farmers have functional land and tree tenurial rights for the adoption of alley farming technology. It is important to note that farmers did not abandon alley farming because of lack of performance in terms of soil fertility or income benefits.

Factors influencing adoption of alley farming and variants

The decision to adopt alley cropping technology is assumed to be a function of three sets of factors: (1) socioeconomic characteristics of farmers, (2) land tenurial rights held by the farmers on the food crop fields where alley cropping is used, and (3) village-specific characteristics.

The results of the empirical model are given in Table 2 for Nigeria and Table 3 for Cameroon. The model for Nigeria gave 70% correct predictions of adopters and nonadopters. Nine explanatory variables were significant in explaining adoption decisions of farmers on alley farming. Results show that the probability of adoption is higher for (a) farmers in contact with research-development and extension agencies, (b) migrant farmers, and (c) farmers in villages facing erosion problems. The probability of adoption is lower for (a) farmers in villages far away from urban centers, (b) farmers producing on rented land, (c) villages with a high abundance of fodder, (d) villages where fuelwood is available, and (e) villages where livestock production is a major income generation activity.

The Logit model for Cameroon gave 76% correct predictions of adopters and nonadopters. The analysis showed that adoption is higher for (a) farmers with contact with extension agencies working on agroforestry technologies, (b) those who belong to farmers' groups, (c) those in areas facing fuelwood scarcity, and (d) those possessing completely secure tree rights. Adoption is lower for (a) farmers in the forest margin zone of the Central province due to low population pressure, relatively long fallow periods, and farmers' general perception that soil fertility is not yet a major problem, and (b) those in villages with an abundant fodder supply.

Effects of policy shifts on the competitiveness and financial profitability of agroforestry-based maize production systems in Cameroon

The economic sustainability of maize through dependence on chemical fertilizers has also been questioned, given the high levels of subsidies on fertilizers that

Table 2. Logit model of adoption of alley farming and variants by farmers in Nigeria

Variable	Expected sign	Coefficient	T-statistic	Elasticity
Constant		16.018	3.847***	
Farmer's characteristics	–	–0.35955	–0.59	–0.22869
Gender: 1 = male; 0 = female				
Family size	–	4.59E-03	–0.229	–0.03418
Level of farmer education	+	–2.06E-02	–0.15	0.01774
Member of associations	+	2.31E-02	2.151**	0.8143
Contact with extension	+	0.99674	2.7***	0.280668
Farmer native of the village	+	–1.6566	–2.506**	–1.02623
Village characteristics				
Land shortage	+	8.79E-02	0.24	0.109225
Erosion index	–	–1.1063	–3.497***	–1.9754
Fuelwood availability	–	–1.7578	–3.2***	–1.92159
Livestock as source of income	+	–0.91775	–2.774***	–1.43803
Distance to nearest town	–	–0.83637	–2.33**	–1.41026
Fodder supply situation	–	–1.9203	–2.002**	–4.03957
Property rights				
Tree rights by sex	–	–1.67E-02	–0.016	–0.0117
Tenurial status	–	–0.12981	–0.314	–0.06364
Rented land	–	–1.9452	–1.86*	–0.058
Right on tree products by gender	–	–0.71324	–1.836*	–0.34024
Log-likelihood function	–112.3605			
Log-likelihood (0)	–138.5811			
Chi-square (16)	52.44121			
Percentage of good prediction	70			

***Significant at 1%; **significant at 5%; *significant at 10%.

provided financial incentives for farmers but which exacerbated social costs. At unsubsidized fertilizer prices, the social profitability of agroforestry-based technologies that rely on internal nutrient cycling would be different, and the interest of both farmers and policymakers in these natural resource management technologies could be expected to increase.

The financial competitiveness of maize production under alternative production technologies has been influenced by two major policy shifts. In 1987, the government of Cameroon began the implementation of measures to correct existing macroeconomic policy distortions. By 1991, the government liberalized input and cereal grain markets while removing direct subsidies on fertilizers, insecticides, and commodities. The removal of fertilizer subsidies increased the fertilizer-input

Table 3. Logit model of adoption of alley farming and variants by farmers in Cameroon

Variable	Expected sign	Coefficient	T ratio	Elasticity
Constant		–5.217***	1.108	
Farmer's characteristics				
Gender: 1 = male; 0 = female	+	–0.108	0.247	0.054
Household size	+	–0.006	0.018	0.040
Level of farmer education	+	0.137	0.111	0.183
Farmer age	+	0.008	0.007	0.278
Membership of farmer groups	+	1.416***	0.254	0.613
Contact with extension	+	2.063***	0.340	1.037
Farmer origin	+	0.125	0.280	0.072
Nonfarm income	+	0.037	0.198	0.011
Village characteristics				
Erosion index	+	–0.093	0.197	–0.125
Fuelwood scarcity	+	0.343*	0.192	–0.475
Fodder abundance	–	–0.277*	0.172	–0.460
Livestock income	+	0.141	0.157	0.207
Land pressure	+	–0.028	0.172	–0.032
Forest zone –	–0.700*	0.413	–0.146	
Property rights				
Secure land rights	+	0.058	0.192	0.021
Secure tree rights	+	1.077**	0.525	0.713
Log likelihood	–330			
Number of observations	701			
Chi-square	175.916			
Percentage of right predictions	76			

***Significant at 1%; **significant at 5%; *significant at 10%.

prices from 50 to 200 FCFA/kg, leading to a decline in the level of fertilizer use by farmers. Another major policy shift with important implications for maize production was devaluation in January 1994. The CFA franc was devalued by 50% with respect to the French franc, leading to major shifts in the relative prices of tradable and nontradable inputs and outputs and the financial competitiveness of crops.

The analysis of financial competitiveness of maize production under alternative technologies was conducted under three time periods: (1) the period before fertilizer subsidies were removed, (2) the period after fertilizer subsidies were removed, and (3) the period after the devaluation of the FCFA (Adesina and Coulibaly 1998). Three measures for assessing profitability were used:

1. Net private profitability (NPP), which is the profit evaluated at private market prices, with all of the inherent distortions. If a commodity has an NPP > 0, it implies that farmers have private incentives to produce.

2. Net social profitability (NSP), which is the profit evaluated at the social prices for both output and inputs. A positive NSP implies that the society gains from the production of the commodity and the production activity uses resources efficiently. If NPP > NSP, it suggests that the effects of the government policy have been to subsidize the commodity production. Thus, NSP > NPP implies a tax on the production activity through government policies.

3. Domestic resource cost (DRC), which is the cost at social prices of nontradable domestic resources used in the production of the commodity divided by the value added at social prices. If DRC < 1, it implies that the production of the commodity represents an efficient use of domestic resources (i.e., has a comparative advantage) compared to imports. DRC > 1 implies that the domestic costs needed to produce the commodity exceed the value added at social or world market prices, and thus the production of the commodity is not efficient in the use of domestic resources (i.e., it lacks a comparative advantage).

The technologies considered include maize production with local and improved varieties with or without chemical fertilizers, and also with alternative resource management technologies such as cover crops and other agroforestry technologies. The data on yields were collected from farmer-managed trials adjusted to reflect yield under nonresearch farm management conditions. The financial prices are real local market prices converted to field prices for each period of the analysis, with subsidy, after subsidy removal, and after devaluation. Tables 4 and 5 show in a summarized form (due to space limitation), some of the important results of the PAM model. See Adesina and Coulibaly (1998) for more details. Some of the major findings from the study are the following:

- Analysis of financial profitability across the three periods shows that all the agroforestry-based maize production systems had a positive NPP, indicating that the farmers have financial incentives to adopt the techniques. One important observation is that, despite the removal of fertilizer subsidies, agroforestry systems that involve the use of fertilizer remained financially profitable. The implication of this finding is that where farmers can afford fertilizers, their use with agroforestry and green manure technologies can significantly enhance financial profits.

- With the removal of subsidies (period 2), the NPP of the agroforestry-based maize production systems has increased substantially compared to fertilizer-based technologies for maize production. Due to the high fertilizer prices, farmers have been observed to make a significant reduction in the use of chemical fertilizers for maize. The financial profitability of the improved fallow technologies with leguminous species (e.g., *Mucuna*, *Tephrosia*, *Sesbania*) supports the observed high level of use of these technologies by farmers in the study zone. Demand for seed of these leguminous species has significantly expanded in the zone.

- The agroforestry-based maize production technologies were found to be also socially profitable (i.e., NSP > 0). Input transfers are nil for the agroforestry technologies without fertilizers but negative for all maize systems using fertilizers. This suggests that farmers producing maize with only agroforestry-based technologies (without the complementary use of fertilizers) obtained no input subsidies from the government. All systems that require the use of fertilizer received input subsidies as farmers paid less for these tradable inputs than the true economic cost.
- Estimates were computed of the effective protection coefficient (EPC) which gives an indication of the net effect of these seemingly conflicting policies in tradable markets. EPC estimates for all technologies ranged from 0.63 to 0.76 for the period when there were fertilizer subsidies (period 1) and from 0.74 to 0.79 for the period when the subsidies were removed (period 2). EPC values < 1 imply that the net policy effects have been largely negative for maize farmers, although with devaluation the net tax effects of overvalued exchange rates have been significantly reduced, and the EPC values were close to 1.
- The computed values for the DRC show that maize production under the agroforestry-based systems has a DRC < 1, indicating that a comparative advantage exists in producing maize under these systems. The lowest DRCs were for (i) improved maize + *Calliandra* hedgerow: 0.38; (ii) improved maize + *Mucuna* + fertilizer (250 kg): 0.41; (iii) improved maize + *Mucuna* + fertilizer (100 kg/ha): 0.44; (iv) improved maize + *Mucuna*: 0.44; (v) improved maize + *Calliandra* + nursery (no plastic bags) in the lowland areas: 0.46; and (vi) improved maize + *Calliandra* + nursery in uplands (no plastic bags): 0.51. Of all the systems considered, only the local maize without external inputs or agroforestry technologies was socially unprofitable (DRC >1).

It can be concluded that maize production under agroforestry-based systems has a high comparative advantage compared to imported maize and maize production relying only on chemical fertilizers, especially after subsidy removal and the devaluation of the FCFA. However, the analysis did not consider how the social profitability of the agroforestry-based technologies may change due to positive externalities. Such positive externalities may include soil erosion control and buildup of soil organic matter over time. The results of this study are therefore conservative. The incorporation of these positive externalities will further increase the social profitability of these natural resource management technologies.

Table 4. The policy analysis matrix for alternative maize production in northern Cameroon: net financial profitability (NFP) (FCFA/ha)

Technology	Before subsidy removal (period 1)				After subsidy removal (period 2)				After devaluation (period 3)			
	Revenue (A)	Costs: Tradable input (B)	Costs: Domestic factor (C)	Net private profitability (NPP) (D)	Revenue (A)	Costs: Tradable inputs (B)	Costs: Domestic factor (C)	Net private profitability (NPP) (D)	Revenue (A)	Costs: Tradable input (B)	Costs: Domestic factors (C)	Net private profitability (NPP) (D)
1. Local maize	36 000	0	75 750	–39750	42 000	0	76 250	–34250	54 000	0	78 500	–245000
2. Improved (Imp.) maize	60 000	0	83 700	–23700	70 000	0	84 850	–14850	90 000	0	87 500	2500
3. Local maize + 50 kg fertilizer	78 000	2500	81 750	–6250	91 000	6000	82 250	2750	117 000	11 000	84 500	21 500
4. Local maize + 100 kg fertilizer	108 000	5000	82 750	20 250	126 000	12 000	83 250	30 750	162 000	22 000	85 500	54 500
5. Local maize + 250 kg fertilizer	138 000	12 500	82 750	42 750	161 000	30 000	83 250	47 750	207 000	55 000	85 500	66 500
6. Imp. maize + 50 kg fertilizer	94 200	2500	90 700	1000	109 900	6000	91 850	12 050	141 300	11 000	94 500	35 800
7. Imp. maize + 100 kg fertilizer	132 000	5000	90 700	36 300	154 000	12 000	91 850	50 150	198 000	22 000	94 500	81 500
8. Imp. maize+ 250 kg fertilizer	165 000	12 500	90 700	61 800	192 500	30 000	91 850	70 650	247 500	55 000	94 500	98 000
9. Imp. maize + *Mucuna*	168 000	0	113 700	54 300	196 000	0	114 850	81 150	252 000	0	117 500	134 500
10. Imp. maize +*Tephrosia*	144 000	0	143 700	300	168 000	0	144 850	23 150	216 000	0	147 500	68 500
11. Imp. maize + *Sesbania*	156 000	0	143 700	12 300	182 000	0	144 850	37 250	234 000	0	147 500	86 500
12. Imp. maize + *Calliandra* (Direct seed broadcast)	181 080	0	103 700	77 380	211 260	0	104 850	106 410	271 620	0	107 500	16 4120
13. Imp. maize + *Calliandra* + nursery + no plastic bags upland fields	216 000	50 000	172 000	–6000	252 000	50 000	173 150	28 850	324 000	70 000	176 300	77 700
14. Imp. maize + *Calliandra* + nursery + no plastic bags inland valley	210 000	0	162 000	48 000	245 000	0	163 150	81 850	315 000	0	166 300	148 700
15. Imp. maize + Calliandra + nursery	210 000	0	147 000	63 000	245 000	0	148 150	96 850	3150 000	0	151 300	163 700
16. Imp. maize + 100 kg fertilizer + *Mucuna*	185 640	50 000	115 700	64 940	216 580	12 000	116 850	87 730	278 460	22 000	119 500	136 960
17. Imp. maize + 100 kg fertilizer + *Tephrosia*	184 980	5000	145 700	34 280	215 810	12 000	146 850	56 960	277 470	22 000	149 500	105 970
18. Imp. maize + 100 kg fertilizer + *Sesbania*	189 540	5000	145 700	38 840	221 130	12 000	146 850	62 280	284 310	22 000	149 500	112 810
19. Imp. maize + 250 kg fertilizer + *Mucuna*	216 000	12 500	115 700	87 800	252 000	30 000	116 850	105 150	324 000	55 000	119 500	149 500
20. Imp. maize + 250 kg fertilizer + *Tephrosia*	192 000	12 500	145 700	33 800	224 000	30 000	146 850	47 150	288 000	55 000	149 500	83 500
21. Imp. maize + 250 kg fertilizer + *Sesbania*	206 400	12 500	145 700	48 200	240 800	30 000	146 850	63 950	309 600	55 000	149 500	105 100

Source: Summarized from Adesina and Coulibaly (1998). Full table is not presented here due to space limitations. For details on the computation of PAM model, see Adesina and Coulibaly (1998).
A = revenue valued at private prices; B = tradable inputs valued at private prices; C = domestic factors valued at private prices; D = NPP = A – B – C.

Table 5. The policy analysis matrix for alternative maize production in northern Cameroon: net social profitability (NSP) (FCFA/ha), comparative advantage, and net effects of policy and domestic resource cost (DRC)

Technology	Revenue (E)	Costs		NSP (H)	Net effects of policy distortions (base model)				DRC
		Tradable input (F)	Domestic factor (G)		Output transfer (I)	Input transfer (J)	Factor transfer (K)	Net policy (L)	
1. Local maize	57 000	0	79 000	22 000	–21 000	0	–3250	–17 750	1.39
2. Improved (Imp.) maize	95 000	0	88 000	7000	–35 000	0	–4300	–30 700	0.93
3. Local maize + 50 kg fertilizer	123 500	10 500	85 000	28 000	–45 500	–8000	–3250	–34 250	0.75
4. Local maize + 100 kg fertilizer	171 000	21 000	86 000	64 000	–63 000	–16 000	–3250	–43 750	0.57
5. Local maize + 250 kg fertilizer	218 500	52 500	86 000	80 000	–80 500	–40 000	–3250	–37 250	0.52
6. Imp. maize + 50 kg fertilizer	149 150	10500	95 000	43 650	–54 950	–8 000	–4300	–42 650	0.62
7. Imp. maize + 100 kg fertilizer	209 000	21 000	95 000	93 000	–77 000	–16 000	–4300	–56 700	0.51
8. Imp. maize + 250 kg fertilizer	261 250	52 500	95 000	113 750	–96 250	–40 000	–4300	–51 950	0.46
9. Imp. maize + *Mucuna*	266 000	0	118 000	148 000	–98 000	0	–4300	–93 700	0.44
10. Imp. maize + *Tephrosia*	228 000	0	148 000	80 000	–84 000	0	–4300	–79 700	0.65
11. Imp. maize + *Sesbania*	247 000	0	148 000	99 000	–91 000	0	–4300	–86 700	0.60
12. Imp. maize + *Calliandra* (direct seed broadcast)	286 710	0	109 500	177 210	–105 630	0	–5800	–99 830	0.38
13. Imp. maize + *Calliandra* + nursery + no plastic bags upland fields	342 000	70 000	178 000	94 000	–126 000	–20 000	–6000	–100 000	0.65
14. Imp. maize + *Calliandra* + nursery + no plastic bags inland valley fields	332 500	0	168 000	164 500	–122 500	0	–6000	–116 500	0.51
15. Imp. maize + *Calliandra* + nursery	332 500	0	153 000	179 500	–122 500	0	–6000	–116 500	0.46
16. Imp. maize + 100 kg fertilizer + *Mucuna*	293 930	21 000	120 000	152 930	–108 290	–16 000	–4300	–87 990	0.44
17. Imp. maize + 100 kg fertilizer +*Tephrosia*	292 885	21 000	150 000	121 885	–107 905	–16 000	–4300	–87 605	0.55
18. Imp. maize + 100 kg fertilizer + *Sesbania*	300 105	21 000	150 000	129 105	–110 565	–16 000	–4300	–90 265	0.54
19. Imp. maize + 250 kg + fertilizer + *Mucuna*	342 000	52 500	120 000	169 500	–126 000	–400 000	–4300	–81 700	0.41
20. Imp. maize + 250 kg fertilizer + *Tephrosia*	304 000	52 500	150 000	101 500	–112 000	–400 000	–4300	–67 700	0.60
21. Imp. maize + 250 kg fertilizer + *Sesbania*	326 800	52 500	150 000	124 300	–120 400	–400 000	–4300	–76 100	0.55

Source: Summarized from Adesina and Coulibaly (1998). Full table is not presented here due to space limitations. For details on the computation of PAM model, see Adesina and Coulibaly (1998). E = revenue valued at social prices; F = tradable inputs valued at social prices; G = domestic factors valued at social prices; H = NSP = (E – F – G); output transfers: I = (A – E); tradable input transfers, J = (B – F); factor transfers, K = (C – G); net transfers for policy effects L = (D – H). (A, B, C, and D are from Table 4.)

Conclusions

Alley farming was developed at IITA as a resource management alternative to slash-and-burn cultivation. With its established advantages, much enthusiasm was generated about the technology. However, the lack of widespread adoption by farmers led to skepticism about its relevance and adoptability. While on-station and on-farm agronomic and economic studies have shown the advantages of this technology, there is a dearth of information on the farmer-level adoption of alley farming, and the financial competitiveness of agroforestry technologies under different policies. The objectives of this study were, therefore, to assess the adoption status of alley farming technology, the factors determining its adoption, and the profitability of agroforestry-based systems in the light of some policy shifts in West and Central Africa.

Evidence from this study shows that earlier skepticism about the adoption potential of the technology appears to be unjustified. Contrary to the conventional view that alley farming technology is being widely rejected by farmers, results of the study show that farmers are adopting the technology in villages characterized by high land-use pressure, soil fertility decline, erosion problems, and fuelwood and fodder scarcity. Results show that, despite an initial slow interest in alley farming, the technology is being adopted by farmers in the three countries. The levels of adoption and retention of alley farming appear to be impressive for a technology that is complex for farmers to manage and which requires major changes in land-use practices. In addition, the technology is undergoing major changes by farmers to suit their circumstances and cropping systems. As farmers look for a better match of the technology with their resources and preferences, they have made important modifications to alley farming, such as the use of a fallow phase. Reasons for not adopting the technology are traceable mainly to technology-related constraints. Solving these constraints requires that researchers focus on modifications that will make the technology more flexible and adaptable to farmers' preferences. As researchers integrate these farmers' modifications in future technology designs, adoption should increase. Such a modified system will need to be targeted to areas where incentives for land-use changes, i.e., land-use pressure, soil fertility decline, and fuelwood scarcity, exist or are likely to occur in the near future.

There is a need for continued efforts to adapt the technology to better fit the needs of farmers. In particular, support for farmer participatory development of variants of alley farming will further encourage wider adoption. But this requires careful targeting of the technology. Many of the earlier efforts to target the technology were based on biophysical characteristics of agricultural systems. However, nonconsideration of socioeconomic models has led to inappropriate targeting of the technology into areas with lower likelihood of adoption in much of West Africa (Whittome et al. 1995). Results from this paper suggest a number of such factors could be used for better targeting of the alley farming system in West Africa.

First, targeting of the technology should continue to focus on areas where erosion is a major problem for farmers. Alley farming has been shown to be effective in reducing the loss of topsoil. Second, the conventional wisdom that alley farming should be targeted into areas where livestock is very important needs careful assessment. In areas where livestock has become a major income source for farmers, land-use preference is likely to be more for intensive fodder banks or extensive grazing agroforestry systems than for alley farming. Also, because cropping becomes less important in such areas, the advantage of alley farming is reduced. Alley farming is more appropriate in areas where cropping is the major income generation activity but where there is some livestock, requiring only small amounts of biomass from the leguminous shrubs and trees as supplementary feeding (Jabbar et al. 1992; Reynolds and Jabbar 1995).

Targeting of alley cropping and its variants should be made using farmers' groups. Participatory development of alley cropping technologies using farmers' groups has proved more successful than targeting to individual farmers (Attah-Krah and Francis 1987; Versteeg and Koudokpon 1993). The farmer-group approach exposes many more farmers to the technology, provides intragroup support for individual experimentation, facilitates farmer-to-farmer interactions in technology testing and management, reduces technology demonstration costs, and increases economies of scale for broad-based dissemination of agroforestry technologies.

The economic analysis has shown a high level of financial and social profitability of alley farming and other agroforestry technologies for natural resource management. The high financial incentive for maize production under agroforestry-based technologies suggests that farmers will adopt resource management technologies provided they contribute to soil fertility and income generation. The high social profitability of maize production under agroforestry-based technologies suggests that increased attention should be given to these technologies, as they represent a socially efficient use of domestic resources. There is need to increasingly target agroforestry-based resource management technologies into areas where preconditions for their adoption exist.

Low rates of adoption of agroforestry technologies could be explained by past inefficient policies. Recent policy shifts in West and Central Africa in the late 1970s and early 1990s have had a positive impact on the financial and social profitability of alley farming and other agroforestry technologies. Therefore, conducive policies are important for the uptake of technologies generated by agricultural research centers such as IITA to achieve sustainable natural resource management and agricultural development in sub-Saharan Africa.

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